Ducts - How Bad? How Important? And How To!

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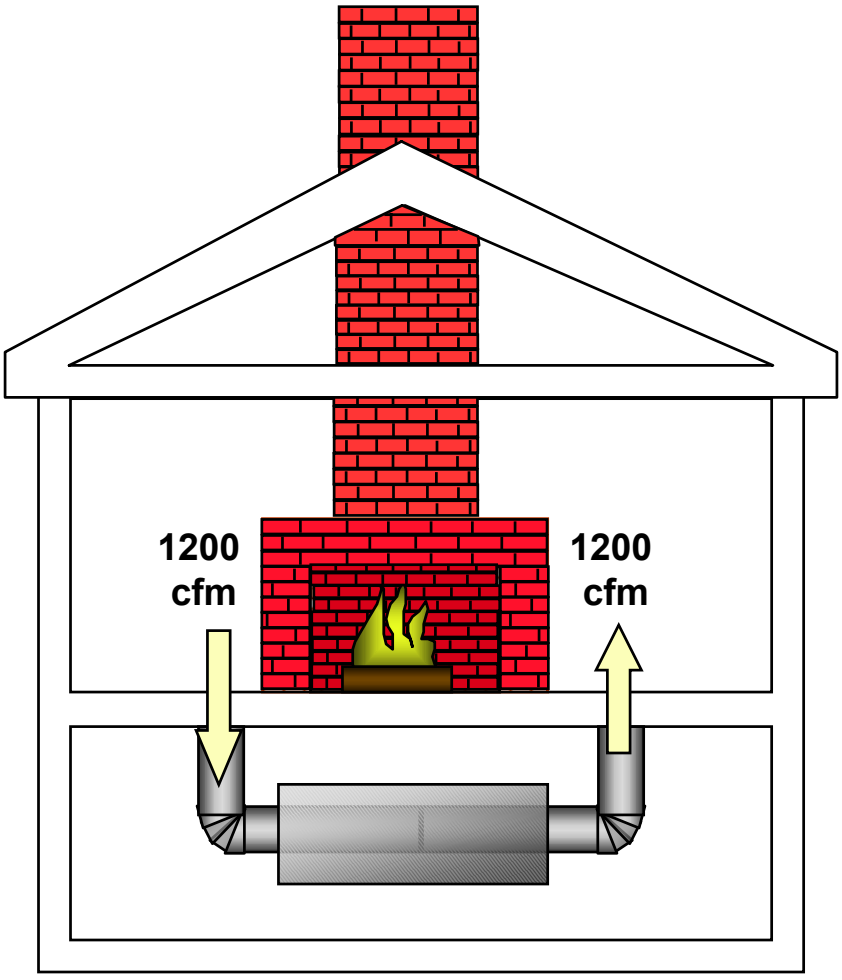
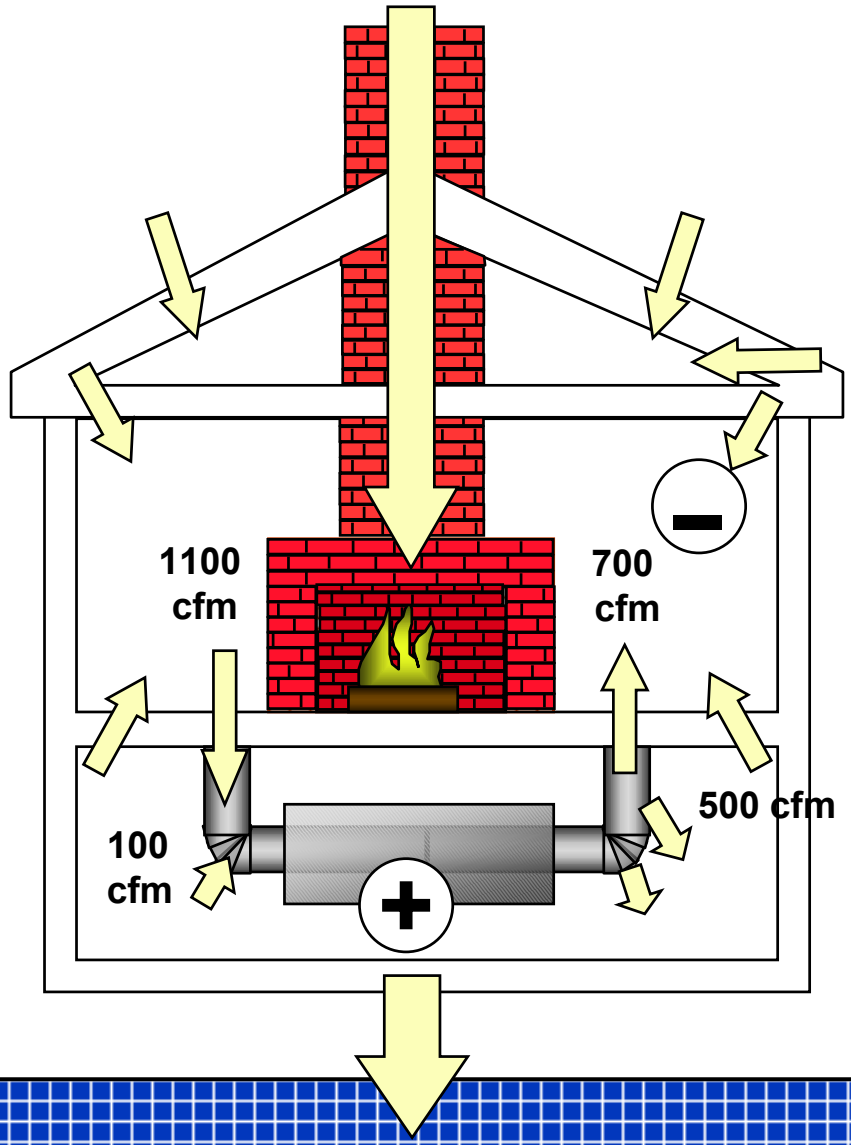
Presenters: Jeff Tiller, PE, Southface Energy Institute and Appalachian State University; tillerjs@appstate.edu, 828-262-6355, FAX 828-264-2333

Tim Eastling, Region IV Department of Energy; Tim.Eastling@EE.DOE.GOV, 404/562-0575, FAX 404/562-0537

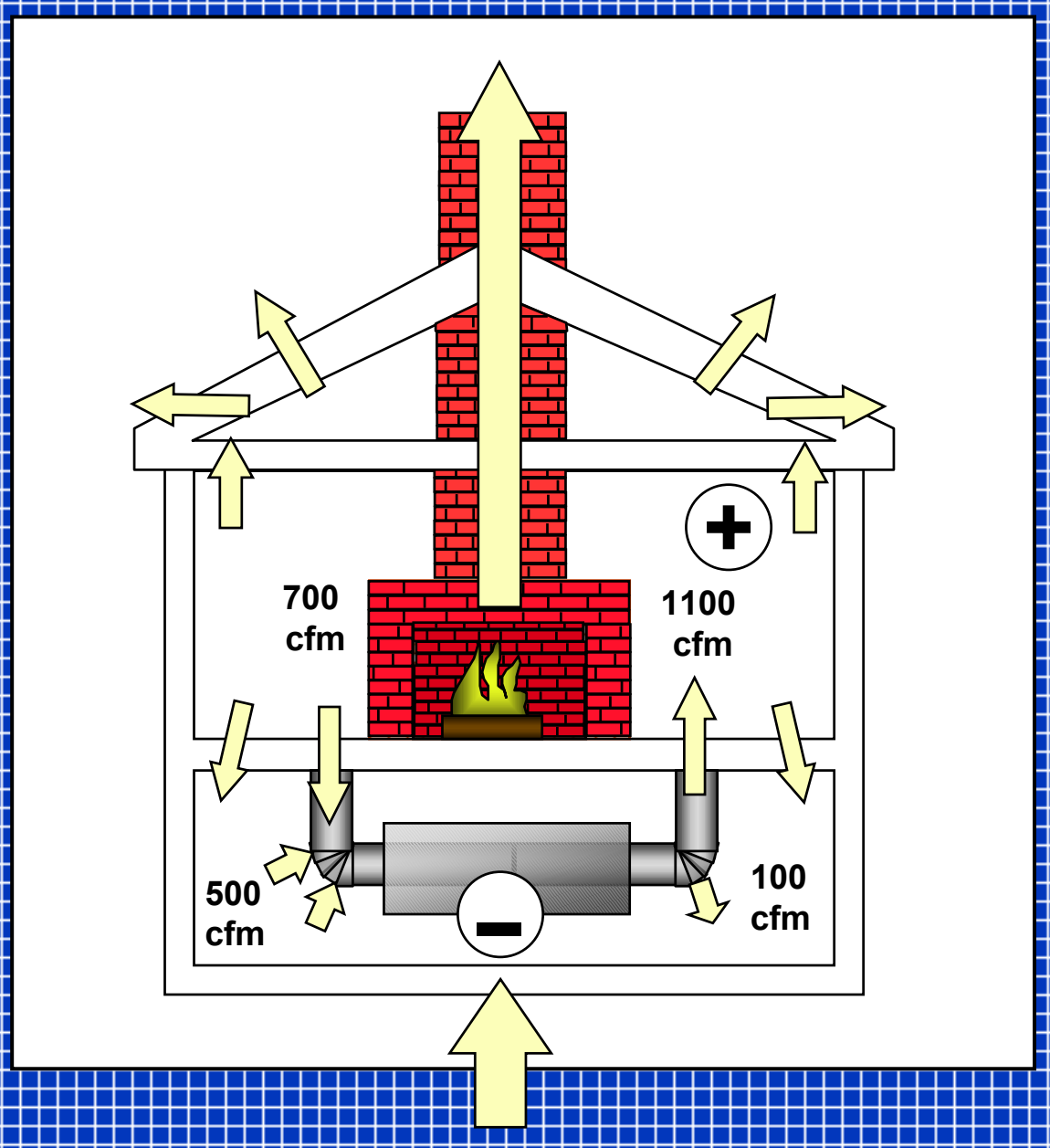
A Balanced System



Supply Leaks Exceed Return Leaks

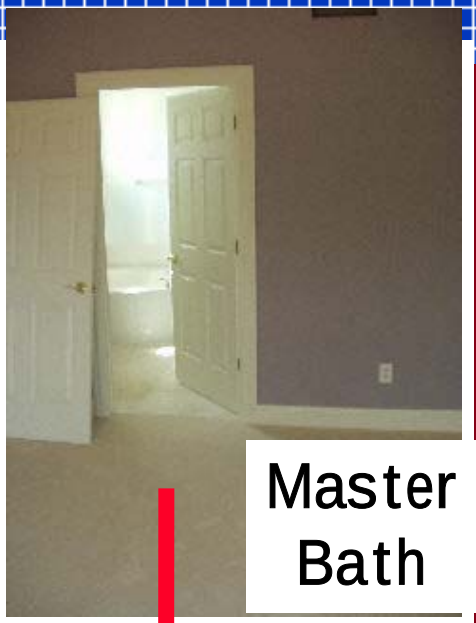


Return Leaks Exceed Supply Leaks

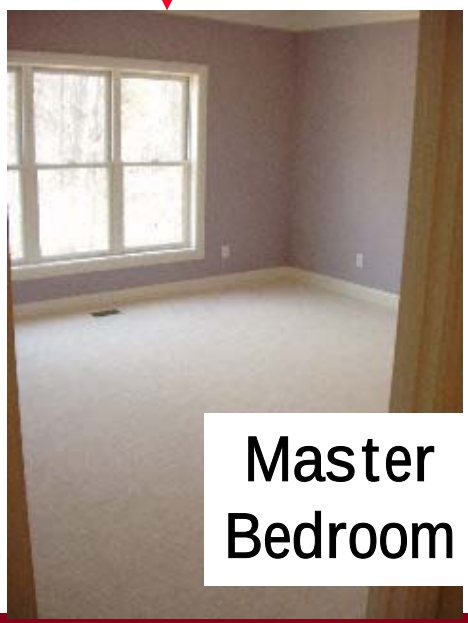


Master Bedroom -- Supplies Need Returns

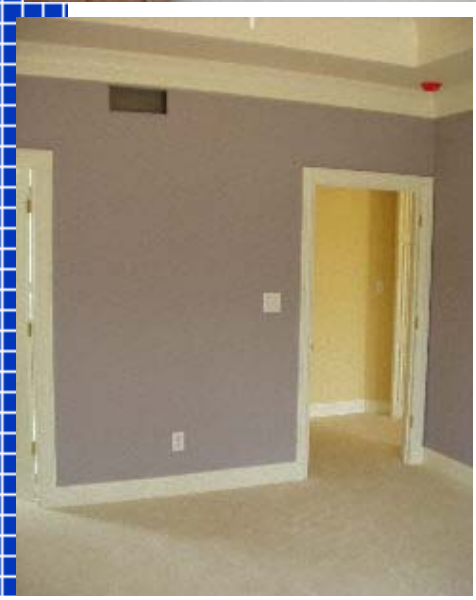
Master Closet



Master Bath

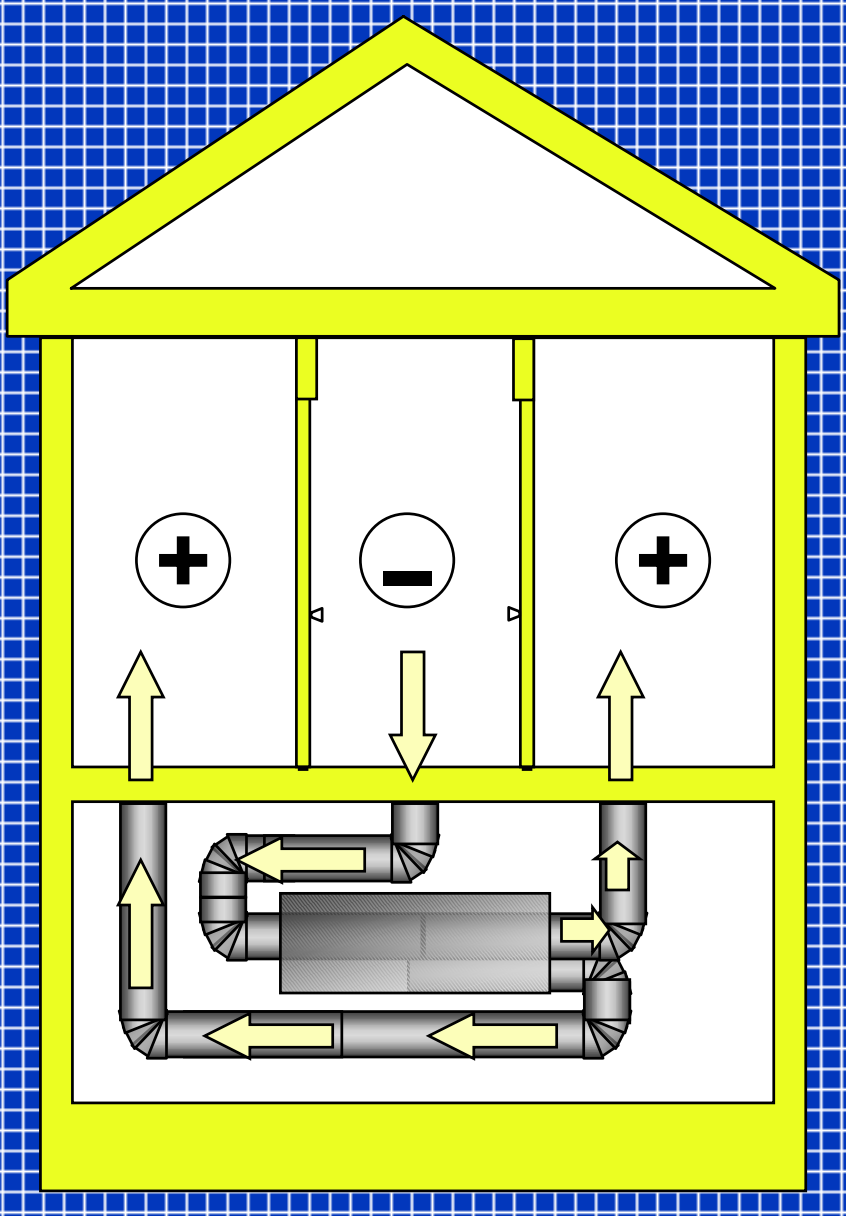


Master Bedroom



Connection to Hallway/ Separate Return

Closing Doors Changes Pressures



Test Result on Nine "Affordable" N. Car. Homes

- 8 homes -- no special attention
- Home #9 -- efficiency measures

Blower Door Results Nine "Affordable" Homes

Hse #	CFM50	ACH50	CFM50 / sq ft
1	1,300	9.2	0.41
2	1,249	8.9	0.39
3	1,300	9.2	0.41
4	1,240	8.8	0.39
5	1,425	10.2	0.45
6	1,625	11.6	0.51
7	1,250	8.9	0.39
8	1,332	9.5	0.42
Avg	1,340	9.5	0.42
9	750	5.3	0.24

Pressure Imbalances -- 9 "Affordable" Homes

Hse #	Fans On	HVAC On	Closed Doors	Worst Case
1	-2.5	-5.0	-6.3	-6.5
3	-0.7	-0.5	-4.0	-6.0
4	-2.0	0.0	-7.5	-8.6
5	0.0	-2.0	-3.6	-4.5
6	-0.5	0.0	-7.3	-8.0
7	0.0	0.0	-2.5	-0.2
8	-2.0	0.0	-3.0	-5.0
Avg	-1.1	-1.1	-4.9	-5.5
9	-4.0	0.0	-10.0	-15.0

Room Pressures with HVAC On

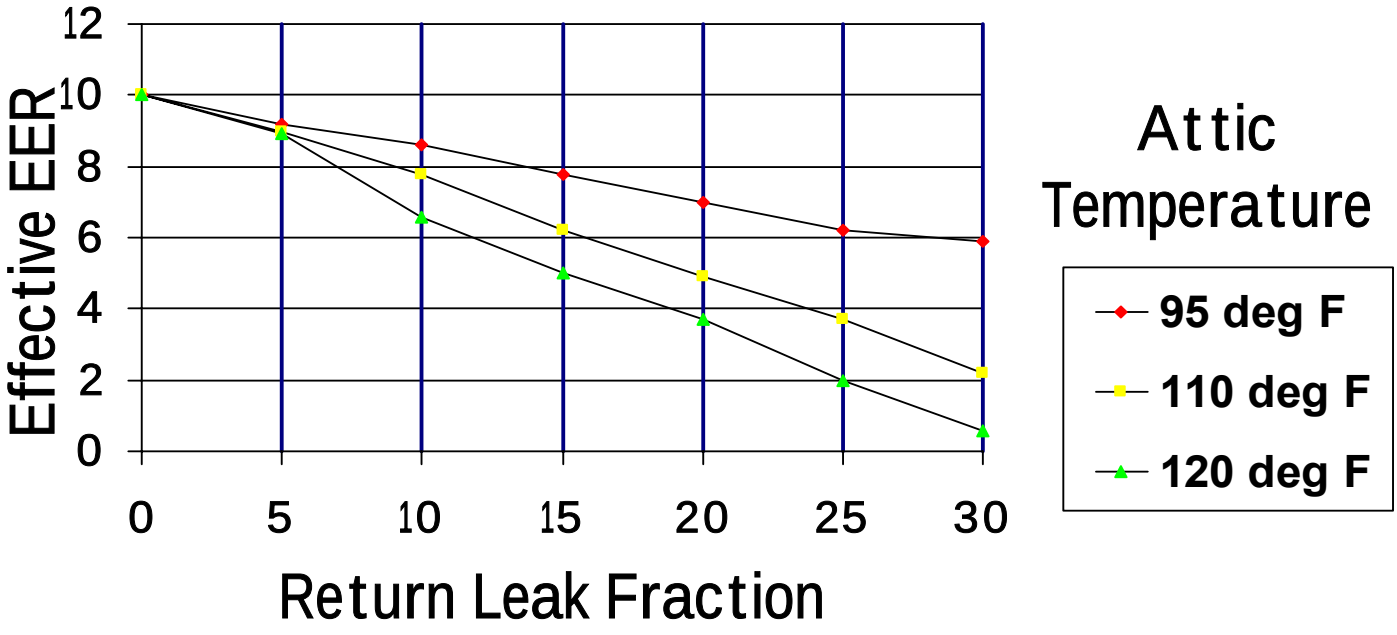
Hse #	Front Bdrm	Master Bdrm	Back Bdrm	Front Bath	Master Bath
1	8.5	5.5	8.5	-	9.5
2	5.0	3.0	10.0	6.0	5.0
3	3.4	7.5	10.8	2.0	1.7
4	3.0	6.5	7.5	4.0	4.0
5	17.0	13.5	1.0	4.0	7.0
6	10.0	2.0	14.5	7.0	2.0
7	1.0	0	0.5	0	0.1
8	5.5	8.5	9.5	2.0	0.5
Avg	6.7	5.8	7.8	3.6	3.7
9	1.8	6.0	5.0	8.5	no duct

Duct Leakage Results -- 9 "Affordable" Homes

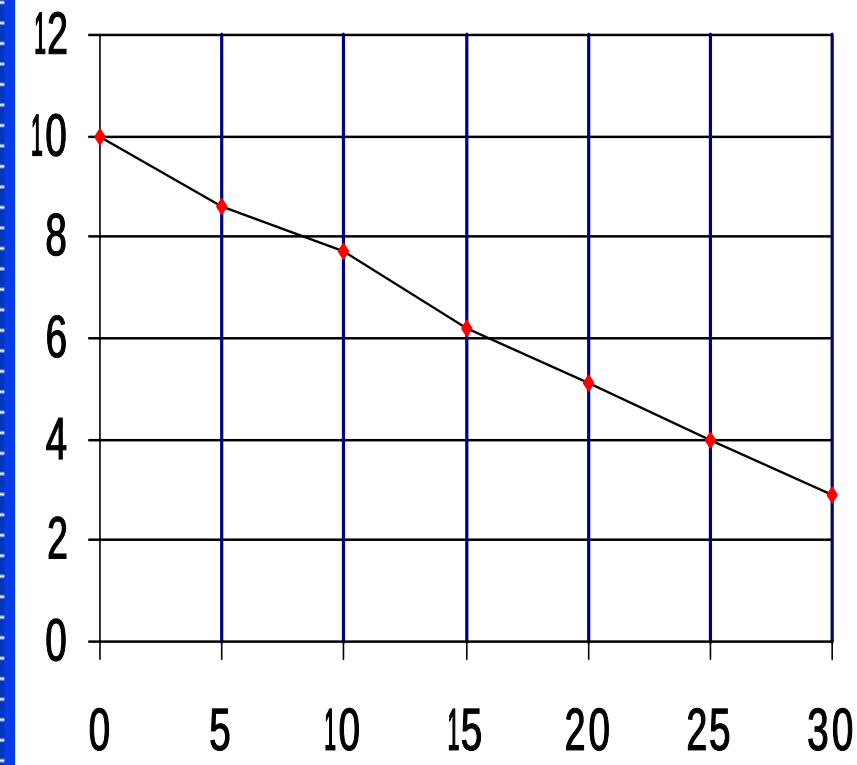
Hse #	CFM25 Total	CFM25 to Outside	CFM 25 as % of Floor Area
1	178	94	9.4%
2	202	71	7.1%
3	223	98	9.8%
4	200	115	11.5%
5	253	138	13.8%
7	175	68	6.8%
8	181	60	6.0%
Avg	202	92	9.2%
9	50	0	0.0%

Note: Goal for tight ducts = CFM25 is 3% of floor area

HVAC Efficiency and Return Leaks in Attics



HVAC Efficiency and Supply Leaks



Average HVAC Systems

- Typical duct systems lose 25 to 40 percent of the heating or cooling energy.
- Systems such as attic ducts in hot, humid climates often lose more.
- If 1/2 the typical loss of uninsulated and unsealed ducts were saved, it would amount to $160 off the total heating bill

(With an average energy cost of 70 cents per them, and 8 cents per kilowatt-hour -- http://eetd.lbl.gov/cbs/success/ducts.html)

Impact of Leaky Ducts

- Each year, leaky ducts increase energy bills by more than $5 billion.
- 20 percent of the energy is wasted because of leaks
- Based on energy savings, the average payback period for sealing leaky ducts ranges from about two to five years
- But leaky ducts do more than increase energy consumption: They also compromise comfort, safety, and indoor air quality.

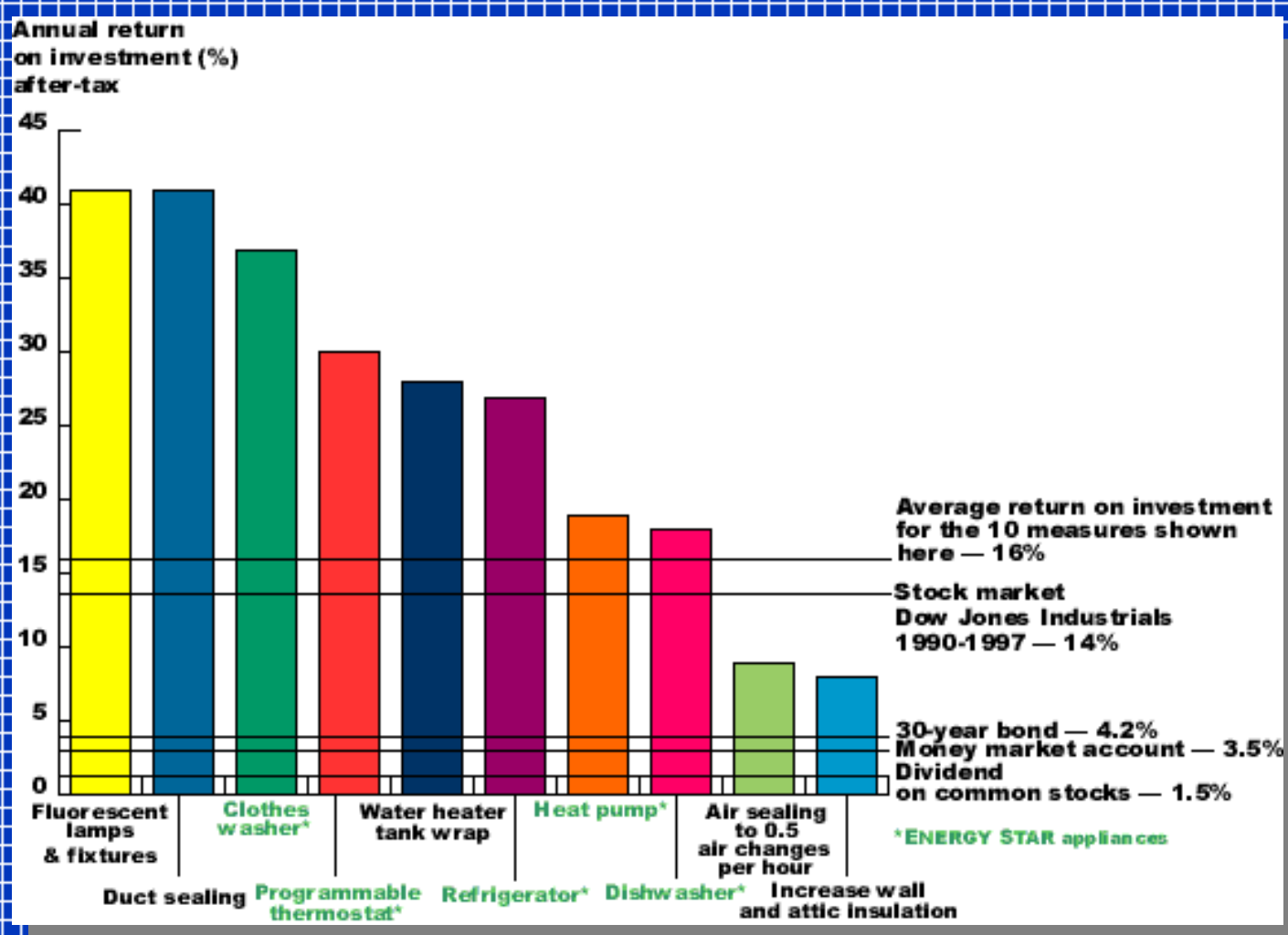
(Los Angeles Department of Water and Energy 2001)

Duct Sealing Saves!

- EPRI estimates that an average U.S. home could expect to save about $200 to $300 a year by sealing duct leaks.
- California contractors charge $500 to $900 for the sealing process for the typical house.
- Assuming other contractors charge similar amounts, the average simple payback period will range from two to four years.

(Los Angeles Department of Water and Energy 2001)

Profitability of Energy Efficiency Upgrades



PATH
(The Partnership for Advancing Technology in Housing 1997).

ORNL Study: Phoenix, Arizona monitored 100 houses

- Located and sealed leaks in ducts in 80% of the houses
- Reduced duct leakage by average of 30%
- Newly sealed ducts reduced their energy consumption by 16% for an annual savings of about $80 per home."
- Retrofits cost $200
- Savings within 3 years

(http://www.ornl.gov/ORNLReview/rev28_2/text/duct.htm)

HVAC & The Environment

- Heating and cooling systems in the U.S. together emit over a half billion tons of carbon dioxide into the atmosphere each year.
- They also generate about 24% of the nation's sulfur dioxide and 12% of the nitrogen oxides, the chief ingredients in acid rain.

Summary of Duct Problems

- Duct leakage can cause pressure imbalance problems in homes
- Closing interior doors can also cause pressure imbalances
- Pressure imbalances and duct leaks
  - Substantially lower HVAC efficiencies
  - Bring poor quality air into the home and may threaten human health
  - Increase air leakage
  - Increase relative humidity in summer
- Duct leakage wastes energy and harms our environment

IECC and Ducts

503.3.3.4.2 Low Pressure Duct Systems

All joints, seams and connections of supply and return ducts shall be securely fastened and sealed with:

- welds
- gaskets
- mastics (adhesives) and mastic-plus-embedded-fabric
- tapes
- installed in accordance with manufacturer's installation instructions
- Exception: continuously welded and locking-type longitudinal joints and seams on ducts operating at less than 0.2 inches w.g.

IECC -- Duct Sealing

503.3.3.4.3 Sealing required.

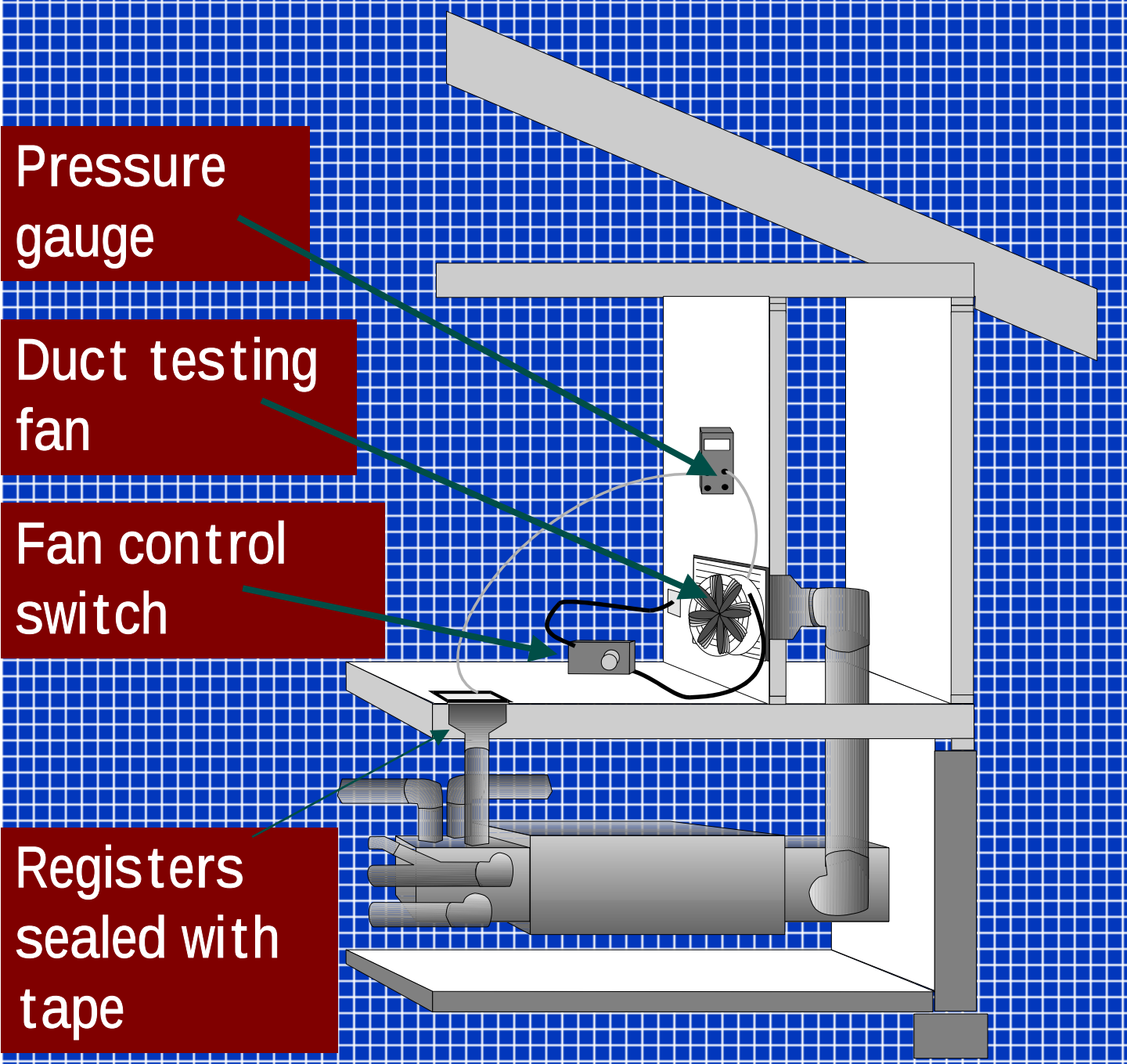
- Tapes and mastics used with rigid fibrous glass ducts -- UL-181A
- Tapes and mastics used with flexible air ducts -- UL-181B
- "Duct tape" is not permitted as a sealant on any ducts

Duct Testing

- You never know about duct leaks unless you test
- Use a duct testing blower system

- Maximize duct leakage, measured in CFM at 25 Pascals pressurization, is 3% to 5% of the home's floor area

Testing For Duct Leakage

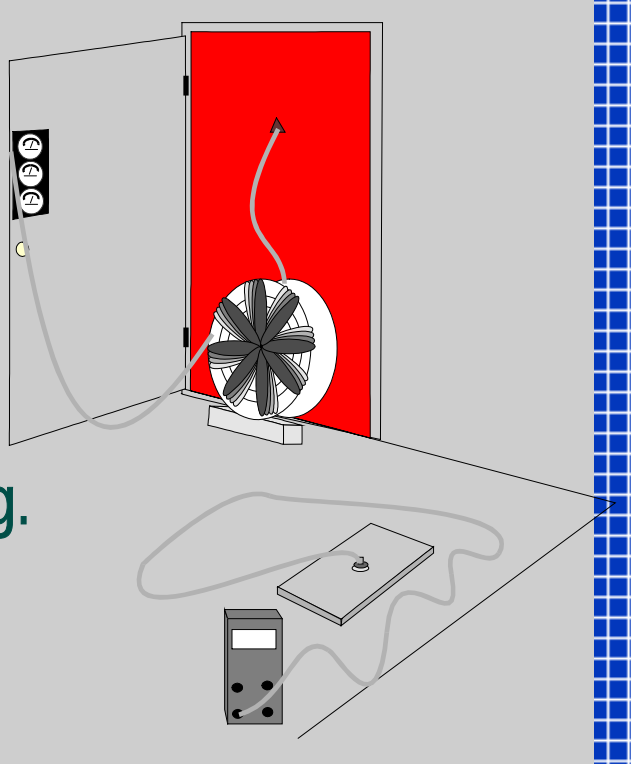


Pressure Pan Testing

1. Set up home for blower door test; do not tape over registers.

2. Bring house to 50 Pascals pressure.

3. Attach digital gauge tubing to the port on the pressure pan.

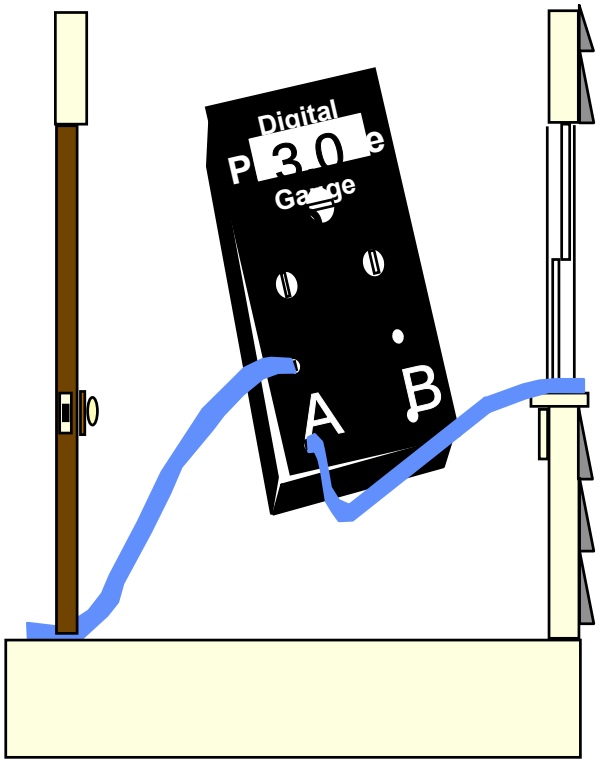


4. Push pressure pan over each register; record pressure gauge reading.

5. If pressure differences over 1 Pascal are found, ducts should be sealed.

Check House Pressures

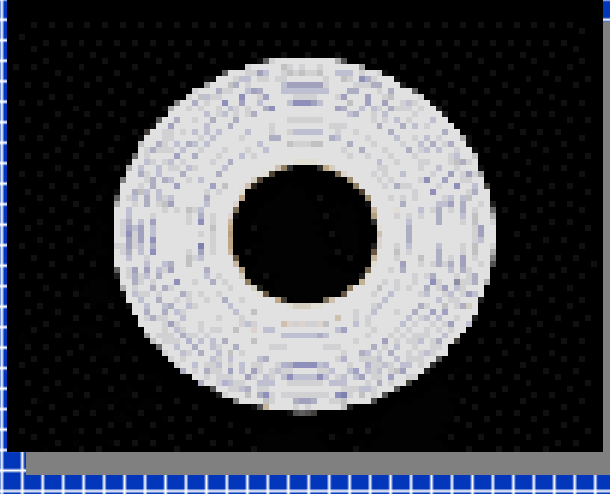
- Test worst case conditions to make certain that conditions do not occur that could backdraft combustion appliances



Duct Sealing Materials

- Cloth duct tape -- not allowed by IECC
- Metal duct tape -- not allowed on most parts of duct system
- Rated metal duct tape (UL-131, etc.)
- Mastic and fiber mesh
- Aerosol spray

Mastic -vs.- Duct Tape



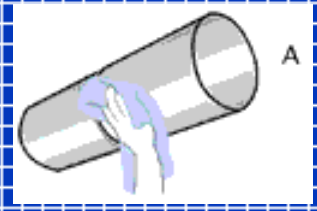
- Test on 31 sealants over three months under accelerated laboratory conditions.
- The sealants applied to ducts were subjected to high flows of air heated to nearly 170 degrees and cold air chilled to below 55 degrees.

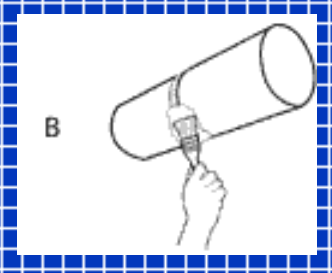
Lawrence Berkeley National Laboratory 2001

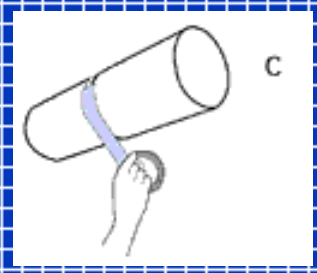
Mastic -vs.- Duct Tape

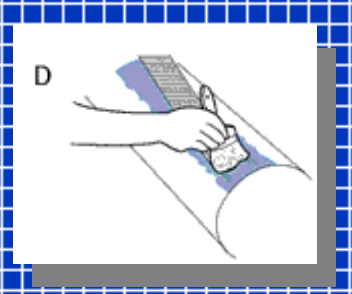
- Of all the things tested, only duct tape failed.
- Instead of duct tape, the researchers recommended sealing ducts with mastic -- a sealant that is painted on and allowed to harden.

Lawrence Berkeley National Laboratory 2001







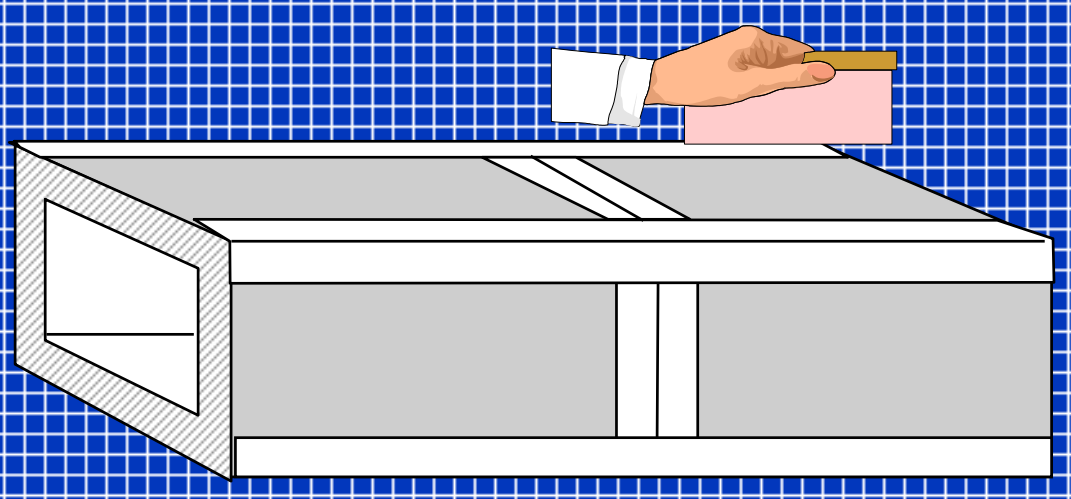


Proper Installation of Rated Tape

- Keep the tape above 50 deg F
- If less than 50 deg F, apply tape with heat iron
- Squeegee the tape

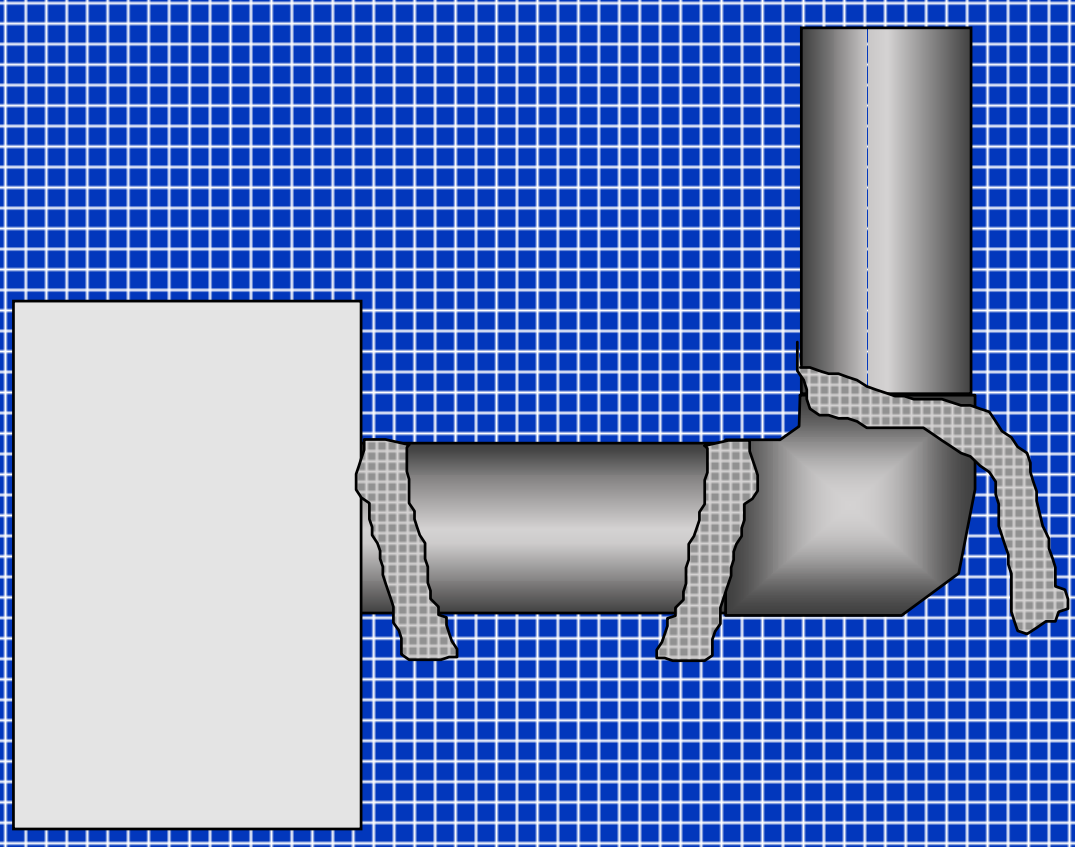
Guidelines for Installing Tape on Ductboard

- Use 2.5-inch minimum width
- 1-inch minimum overlap
- Squeegee tape in place, avoiding excessive pressure



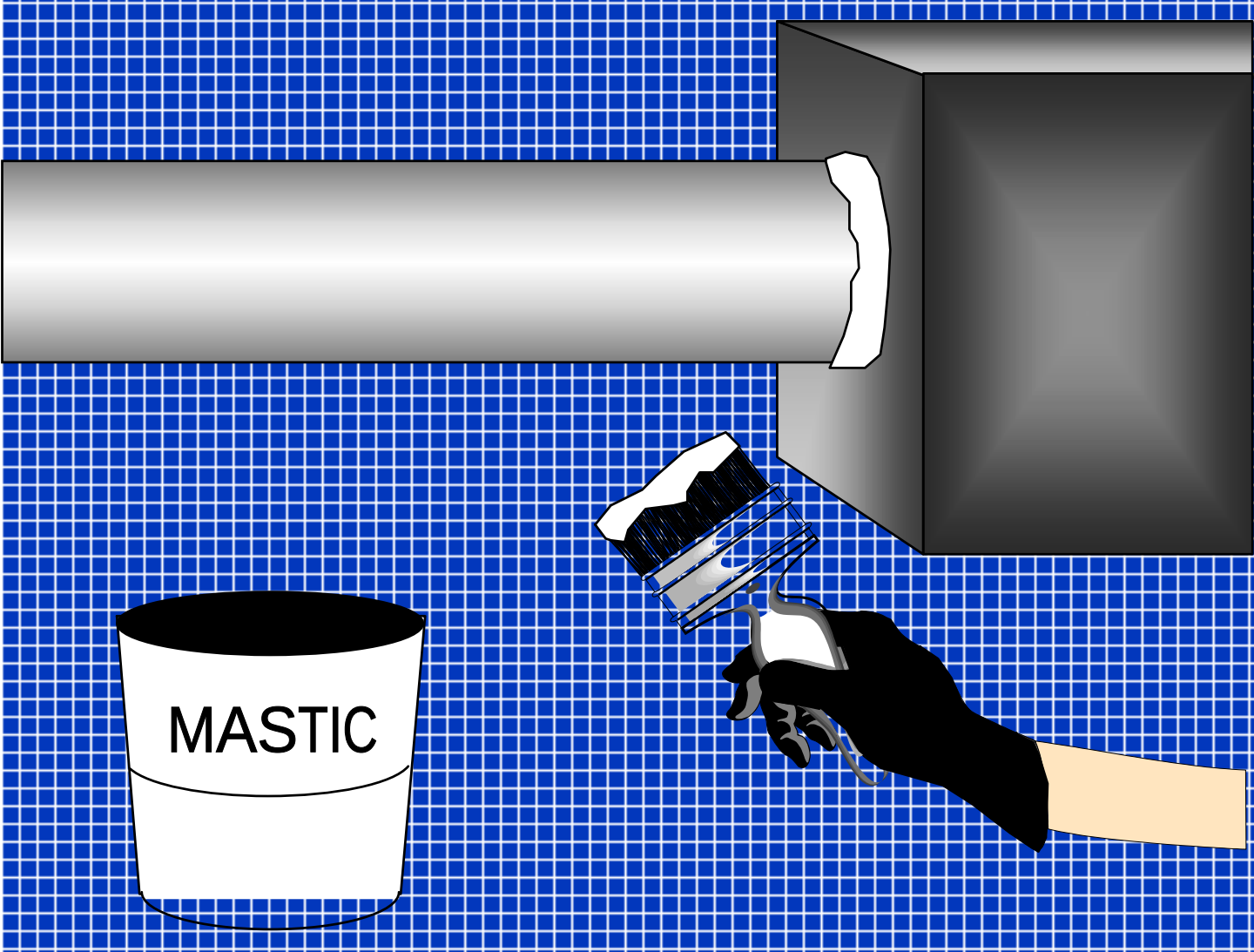
Problems with Tapes

1. Unrated tapes are often used. Proper tapes have a UL-181 label.
2. Short shelf life.
3. Rated tapes are not usually installed properly.
4. Below 50 Deg F, tape must be ironed.
5. Tape is designed for smooth, straight joints.



Tape Often Does Not Last The Life of The Ductwork

Duct Sealing -- Mastic Works



Duct Sealing

Use duct sealing mastic
(with mesh tape on gaps over 1/4”)

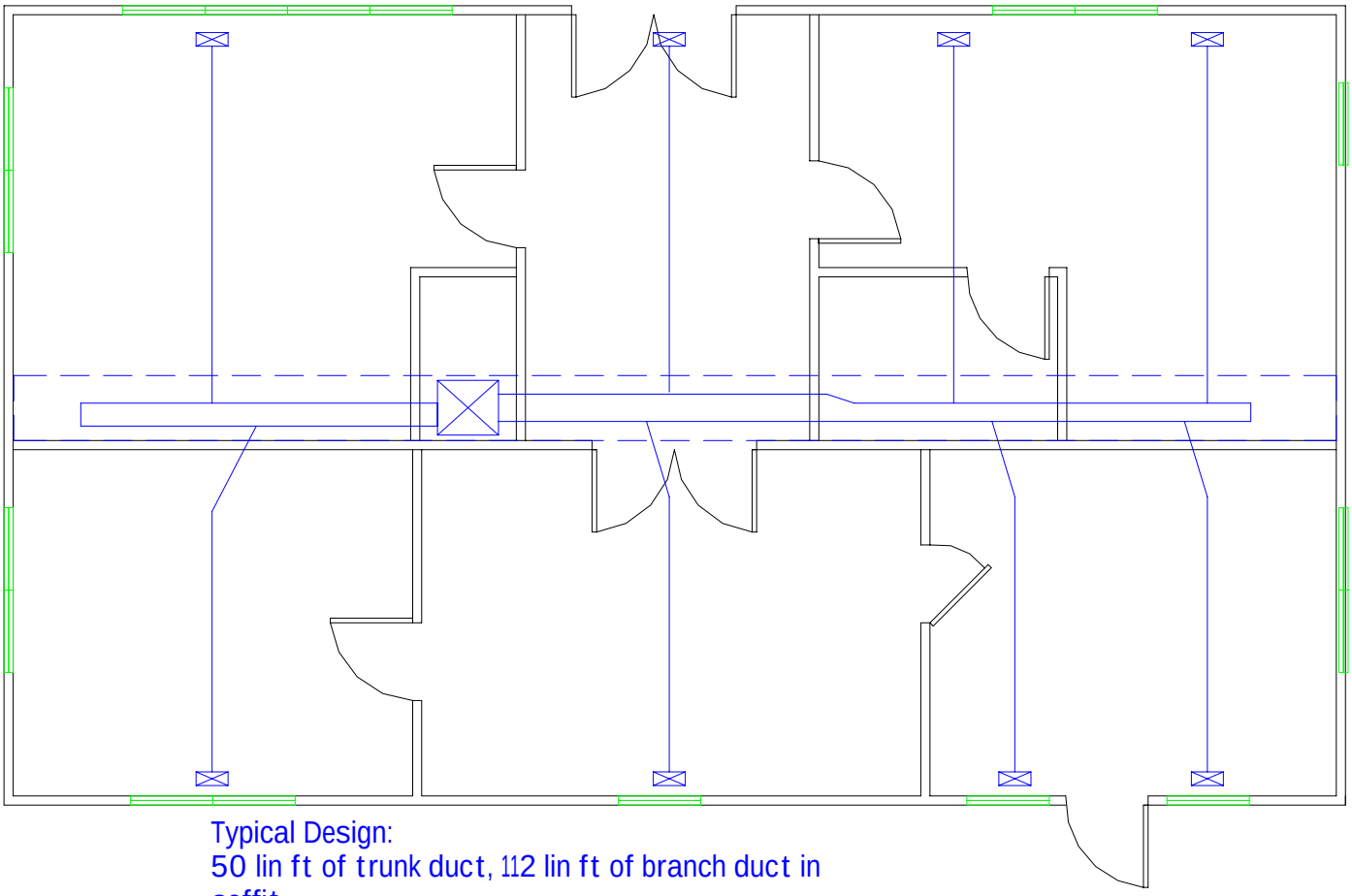
Duct Insulation

Temperature Conditions		
	Summer	Winter
House		
Attic	135° F	25° F
House Interior	75° F	70° F
Difference in Temperature	60° F	45° F
Required Insulation	R-30 to R-38	
Duct		
Attic	135° F	25° F
Duct Interior	55° F	120° F
Difference in Temperature	80° F	95° F
Required Insulation	R-4 to R-6	
Recommendation -- Increase duct insulation levels		

Other Duct System Recommendations

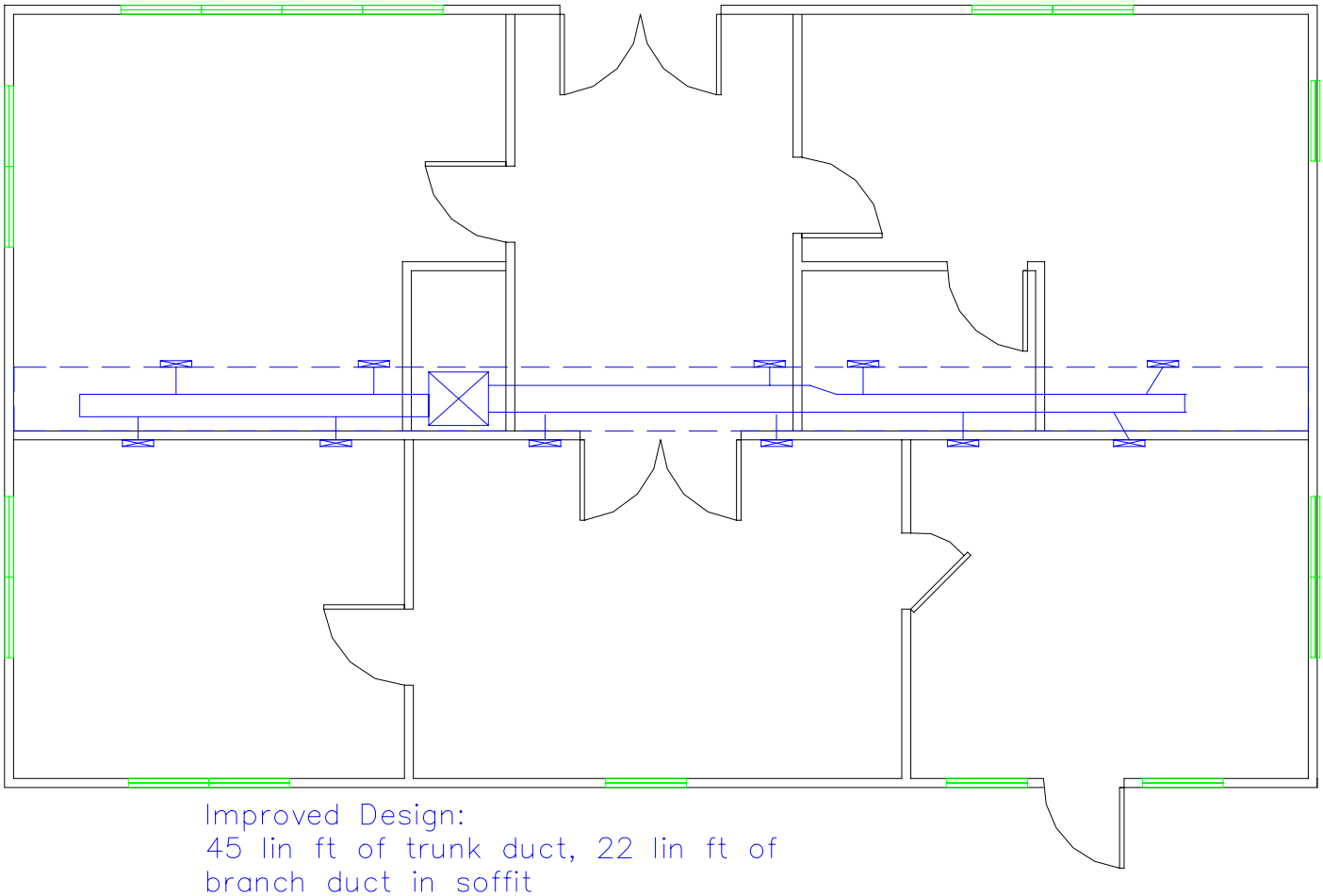
- Flex duct and ductboard sealants must meet UL-181A and B
- Inner liner of flex duct must be sealed to the take-off that is mechanically fastened to the plenum
- Sheet metal duct sealants -- recommend duct-sealing mastic with fiber-mesh tape for cracks or holes larger than 1/8” inch
- Ducts shall be sized according to ACCA Manual D or SMACNA residential standards

Typical Duct Design



Typical Design:
50 lin ft of trunk duct, 112 lin ft of branch duct in soffit
250 sq ft of duct in attic

Improved Duct Design



Improved Design:
45 lin ft of trunk duct, 22 lin ft of branch duct in soffit
0 sq ft of duct in attic

Bring Ducts Inside Conditioned Space

- Use dropped soffits and chases
- Completely seal duct chase to the exterior, attic, crawl space, or basement
- Connect rooms with more than one supply to the main return via transfer grilles

Standard Approach -- Return in Attic

Standard Approach -- System and Supply in Crawl Space

Improved Affordable Home HVAC/ Duct System

Most of System Inside

Dropped Hallway Ceiling

Comparison of Air Flow in Different 6-inch Ducts

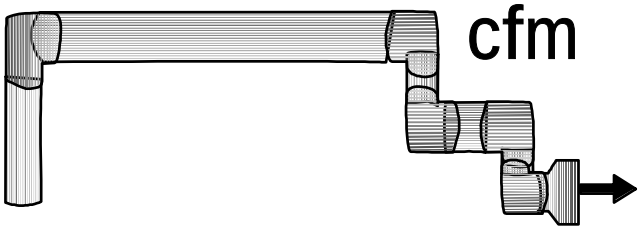
130cfm

Short Metal

110cfm

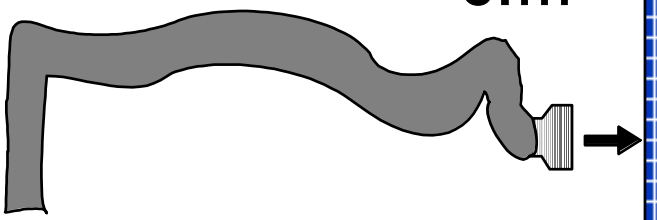
Short Flex

100 cfm



Long Metal

75 cfm



Long Flex

Duct Design Summary

- Use Manual D or other duct sizing calculation
- Install ductwork properly
  - straight runs
  - no crimps
  - proper hangers
- Install returns in rooms with more than one supply duct
- Duct insulation -- at least R-6 in attics and crawl spaces

Ducts Sized Right, Then Installed Poorly

Quantifying Leakage

Approximating air leakage through a crack or seam:

$1.06 * \text{Area(sq in)} * P(\text{Pa})^{0.65}$

Suppose there is substantial leakage around the filter rack of the main return.

The filter rack is 16" tall and 1" wide; the cracks are about 1/4" wide times the 16" length

The area of the filter rack in square inches = 16" * 1/4" = 4 sq in

Leakage Example 1 (continued)

If the return grille, located directly behind the blower, is subject to 60 Pascals of pressure, then the duct leakage =

$1.06 * 4 \text{ sq in} * 60^{0.65} = 61 \text{ cfm}$

Leakage Example 2

Suppose there is substantial leakage around the boots just before the supply air enters the rooms.

The leaks are 72 inches long by 1/16"; the area = 72" * 1/16" = 4.5 sq in

The supply boot is subject to only 10 Pascals of pressure

Thus, the air leakage = 1.06 * 4.5 sq in * $10^{0.65}$ = 21 cfm

Impact on HVAC Capacity

What would each leak add to the heating load of the house, assuming they were located in a climate with a heating design temperature of 15 degrees F and that the attic followed outdoor temperatures fairly closely.

Btu per hour = 1.1 * difference in temperature * cfm

Impact on HVAC Capacity (continued)

Leak in filter grille (61 cfm):

When air leaks in the duct system, the heating system must heat it up to the supply temperature; thus, it has to heat the 15 degree air up to about 70 degrees F -- a 55 degree differential

Btu per hour = 1.1 * difference in temperature * cfm = 1.1 * 55 * 61 = 3,700 Btuh

Impact on HVAC Capacity (continued)

Leak at supply boot (21 cfm):

When heated air escapes from the duct system, the homeowner loses the amount of heat the furnace added to the air. Assuming the air is heated from 70 degrees F to 115 degrees F, a 45 degree differential, the system loses:

Btu per hour = 1.1 * difference in temperature * cfm = 1.1 * 45 * 21 = 1,040 Btuh

Impact on HVAC Capacity (continued)

If the HVAC system has a capacity of 40,000 Btuh of heating

The 3,700 Btuh leak at the filter grille is 9.25% of total capacity

The 1,040 Btuh leak at the supply boot is 2.6% of total capacity

Many systems assume 5% to 10% duct losses or less, which also include leakage through duct insulation.

Summary of Duct Testing Methods

- Subtraction Method (blower door only) -- a poor test of tight ducts/ can find leaky duct systems
- Duct testing fan -- finds total duct leakage
- Blower door/ duct testing fan -- tests duct leaks to the outside
- Pressure pan -- finds leakiest ducts
- New methods (Delta Q, etc.) try to find actual duct leakage during HVAC system operation -- avoid overstating amount of duct leakage in systems with leaks near boots

Abbreviated Summary

- Duct sealing is one of the major, if not the single major problem in new home efficiency
- The IECC has modest provisions requiring tighter duct systems
- All concerned with state energy codes should seek improved enforcement of the duct sealing provisions and consider tougher measures